Life Cycle Assessment of Biomass supply chains

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Centre for Environment & Sustainability previously Centre for Environmental Strategy

Established 1992 by Professor Roland Clift as a multi-disciplinary centre for research & teaching on ‘sustainability’.

Currently ~12 academic staff, 10 visiting staff, 10 Post-docs/academic visitors, 50 PhD/EngD/Practitioner Doctorates:

• **sustainable systems analysis**
  – LCA, sLCA, carbon footprinting, agent-based models, multi-criteria decision making, supply-chain and value chain analysis

• **social research on sustainability**
  – values, attitudes, behaviours, lifestyles with departments of Psychology, Sociology, Economics

• **policy/governance and corporate sustainability strategy research**
  – risk, roles of innovation, CSR, communication, regulation
CES: Multi-disciplinary research & analysis on environment and sustainability

- Material & Energy Flows
  - Environmental Impact
  - Material Flow Analysis
  - Energy Analysis
- Life Cycle Assessment
- Carbon Footprinting
- Effect of Economic Factors
  - Environmental Input Output Analysis
  - Economic Value Chain Analysis
- Decision Support
- Policy Analysis
- Social Value Chain Analysis

Novel Problem Structuring Techniques - Stakeholder engagement, participatory approaches

Multi-Criteria Decision Analysis

Complexity Science & Modelling
Aims

• Brief introduction to LCA

• Background to bioenergy & biofuels

• Detail example(s) of bioenergy production

• Identify areas for innovations/opportunities in bioenergy supply and use
LCA is a **systems analysis** tool to describe the ‘cradle-to-grave’ environmental impacts of products, processes and services


- LCA is now a ‘mature’ approach for characterising ‘eco/environmental profiles’
LCA is a systems analysis tool to describe the ‘cradle-to-grave’ environmental impacts of products and processes

*Cradle-to-Gate and Gate-to-Gate variants*
LCA under the ISO 14040 series

Direct Applications:
- Product development and improvement
- Strategic planning
- Public policy
- Marketing
The key objectives of LCA studies are :-

- **Completeness**
  - a holistic view, we use several indicators of environmental impact e.g. global warming potential, acidification, ecotoxicity ....
  - avoid ‘single issue’ distortion

- **Transparency**
  - for reviewers/practitioners
  - for decision makers
LCA studies are usually ‘iterative’:

1st iteration
- full product system
- specific data as available
- easily available secondary data

2nd iteration
- revision of scope definition?
- better data for key processes (background and foreground)
- more specific data for foreground processes

3rd iteration
- better data for key processes and flows (background and foreground)

see ILCD Handbook
A typical Life Cycle System Boundary

from ‘Corrugated packaging Life-Cycle Assessment: Summary Report’ by PE Americas/Five Winds for the Corrugated Packaging Alliance
Bioenergy - *the GHG rationale*

**Figure 7: Lifecycle GHG emissions (excluding land use change) per unit of output for a range of bioenergy (green) and fossil (black) options**

- **Biomass** (wood chips, pellets)
- **Biomass co-firing** (biomass fraction)
- **Biogas** (waste and residues)
- **Coal**
- **Oil**
- **Natural gas**
- **Biomass (wood chips, pellets)**
- **Coal**
- **Oil**
- **Natural gas**

Note: Based on current state of technologies. Ranges reflect variations in performance as reported in literature. Possible emissions from land-use change are *not* included here.

Source: Based on Cherubini et al., 2009; IPCC, 2011.

Bioenergy in the UK

Biomass will be important in the UK’s energy supply by 2020 e.g. approx. 12 million tonnes/yr used for electricity production

Total UK energy consumption in 2020 predicted as ~1550 TWh/y

See Stephenson & MacKay, 2014
Bioenergy in the UK

*Biomass to energy is not ‘simple’. Report by Deloitte identifies 5 obstacles to overcome:-*

- Regulation
- Availability of the fuel
- Sustainability credentials
- Supply chain
- Financing

Life Cycle Assessment (LCA) of Local SE UK Wood Energy Supply Chains

Weiqun Wu

October 2014

Supervisors:
- Richard Murphy
- Martin Head
- Roland Clift
  CES, University of Surrey
  CEP, Imperial College London
  CES, University of Surrey

Participating Company: LC Energy Ltd, Surrey UK
LCA Approach

- Literature review
- Goal and scope
  - Defining boundary
- Data collection
  - Data questionnaires
  - Literature
- Data analysis and interpretation
  - Comparing two cases
  - Comparing wood energy with fossil fuels
System boundary – Surrey University Sports Park (SSP)

- Fuels, Chemicals, Machinery, Raw Materials
  - Forest Wood
    - Planting
    - Management
  - Felling & Extracting
    - Thinning
    - Clear felling
- Fuels, Machinery
- Fuels, Vehicles
- Fuels, Machinery, Vehicles
  - Processing
    - Chipping
    - Storage
    - Chipper transport
    - Rehandling
- Fuels, Vehicles
  - Energy User
    - Combustion
    - Maintenance
    - Disposal of ashes

Emissions to air, water and land
Functional unit

The functional unit acts as a reference flow, which connects all other modelled flows. The functional unit was:

- the annual supply of wood fuel energy at SSP = 1,114,030 kWh of heat.

- Comparison was done with ‘heat production by natural gas, at industrial furnace >100kW’ and ‘heat production, at hard coal industrial furnace 1-10MW’.
Results - process contributions

- Terrestrial ecotoxicity
- Photochemical oxidation
- Ozone layer depletion
- Marine aquatic ecotoxicity
- Human toxicity
- Freshwater aquatic ecotoxicity
- Eutrophication
- Depletion of fossil fuels
- Depletion of abiotic resources
- Climate Change-GWP100a
- Acidification

Legend:
- Blue: Combustion of wood chip
- Red: Furnace use
- Purple: Transportation
- Cyan: Wood chipping
- Green: Disposal of ashes
- Orange: Forest

Prof Richard Murphy, Centre for Environmental Strategy (CES)
Results - SSP

Acidification

- Combustion of wood chip: 67%
- Furnace use: 9%
- Disposal of ashes: 5%
- Transport of chip to SSP: 2%
- Transport of wood to hub: 1%
- Transport of chipper: 7%
- Wood chipping: 4%
- Harvesting: 4%
- Forwading: 1%
- Forestry management: 1%
Results - SSP

Climate Change-GWP100a

- Furnace use: 14%
- Transport of chip to SSP: 3%
- Transport of wood to hub: 12%
- Transport of chipper: 3%
- Wood chipping: 19%
- Harvesting: 7%
- Forwading: 3%
- Forestry management: 30%
Results - SSP

Graph showing the comparison of different environmental impacts (coal, natural gas, SSP) for various categories such as Acidification, Climate change - GWP100, etc. The bars indicate the percentage contribution of each category to the overall impact.
Summary – GWP$_{100}$

- GWP in this study was 15.6 kg CO2e/MWh

For a ~500kW boiler literature values are approx.:

- 18 kg CO2e/MWh on UK forest residue or chips
- 30 kg CO2e/MWh for pellets UK (dry wood)
Discussion

- Wood chip - better performance compared with fossil fuels, especially in global warming, ozone layer depletion and photochemical oxidation.

- **Transportation** and Chipping operation each account for ~30% of GWP impact

- **Ash disposal** is seen to impact eutrophication, wood chip is not better in this regard compared with natural gas.
Extension of studies at CES
- *LC Energy* w/ Alexander Dale MSc
- *Forestry Commission* w/ ESRC SE-DTC PhD

Caroline Greenslade *(w/ Reading University)*

- Building on the LCA systems analysis to add in £ and social factors.

- Modelling the bottlenecks, pinch points and opportunities in achieving enhanced woodland use in SE England.
Opportunities and Perspectives

- LCAs help refine our perceptions of ‘greenness’

- Life cycle thinking is needed for ‘green’ design/redesign of environmentally successful products

- LCAs are essential to making sound decisions and assertions about ‘green’ products

- LCAs may be used directly or to support Environmental Product Declarations (e.g. ISO 14025 etc) and to generate specific output for Carbon footprinting
Biofuel technologies & Integration

An opinion .... 2G biofuels offer real advantage with application of an integrated systems approach.

from Sune Wännström at SEKAB E-technology
e.g. Bamboo bioethanol vs petrol - China

China bioethanol pump price (2011) ‘current’ policy includes a $0.16 per litre subsidy and fuel excise & VAT exemptions

Fig. 3 Fuel pump price comparison of bamboo bioethanol using three pretreatment processes with petrol in China. Left columns represent current scenarios and right columns future scenarios.

from: Wang et al. 2014 RSC Advances 4, 29604 - 29611
Bioethanol all feedstocks - SUMMARY

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<th>Wheat straw w/ policy</th>
<th>SRC poplar, willows</th>
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¹estimated

- **Economic factors generally impose greater constraints than environmental factors**

- **Beware of pre-conceptions and assumptions - some feedstocks are highly constrained, others e.g. SRC show much more flexibility**

- **Policy effects are critical**
Opportunity – ‘designer’ biomass feedstock

Research progress to ‘design’ 2G feedstocks

e.g. analysis of saccharification yields in willow populations enables discovery of QTL for biofuel - collaboration with Rothamsted Research see Brereton et al, 2010 Bioenerg. Res. DOI 10.1007/s12155-010-9077-3

also EC FP7 project EnergyPoplar
Biomass/Feedstock opportunity

Discovery - the reaction-wood phenotype in willows has big advantages for 2G biofuel conversions

see Brereton et al, 2012 Biotechnology for Biofuels
http://www.biotechnologyforbiofuels.com/content/5/1/83

See also Imperial website
Italy lowest production cost – *high biomass yield & high FiT*

*BUT*

Highest excise, highest VAT

Sweden & Slovakia most price ‘competitive’ – *full tax exemption*
Closing remarks…..

Clear benefits and opportunities for biomass, with wood biomass having a leading role

Without a demonstrable environmental ‘credit’ products are forced to compete only on price and technical performance

LCA and environmental information is at its most powerful when combined with techno-economic analysis and social impact assessment so we can achieve an integrated sustainability assessment …..
Acknowledgements

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